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The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(7): 906-909

www.thepharmajournal.com
Received: 16-05-2022
Accepted: 27-06-2022

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Growth and yield response of different Ajwain (*Trachyspermum ammi sprage*) based intercropping systems under Semi-arid Eastern Plain Zones of Rajasthan

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Abstract
A field experiment comprising ten treatments of intercropping systems replicated four times, was conducted in Randomized Block Design during *rabi* season, 2016-17. Results revealed that sole ajwain exhibited the higher plant height and number of branches plant^{-1} at 60, 90 DAS and at harvest as compared to different intercropping system. Further, results showed that sole ajwain gave significantly highest values of yield attributes *viz.*, number of umbels plant^{-1}, number of umbellate umbel^{-1}, seeds umbellate^{-1}, 1000-seed weight, seed yield plant^{-1} and seed yield ha^{-1} as compared to different intercropping system. Sole french radish, sole Knolkhol and sole fenugreek resulted higher plant population, plant height at harvest, number of leaves plant^{-1}, diameter of curd and fresh marketable yield as compared to different intercropping systems. Intercropping of ajwain with french radish in 1:1 row ratio resulted significantly higher land equivalent ratio (1.81), ajwain equivalent yield (3274 kg ha^{-1}), gross return (Rs. 327388 /- ha^{-1}), net return (Rs.270238/- ha^{-1}) and BCR (4.72) followed by intercropping of ajwain with french radish in 2:2 paired row ratio. Ajwain + Fenugreek 1:1 and 2:2 recorded significantly higher N, P and K (90.09, 6.92 and 282.52 kg per ha) availability in soil after harvest of crops as compared to other intercropping. Thus, it is inferred that intercropping of ajwain + french radish in 1:1 row ratio is better for realizing higher system productivity and economic returns.

Keywords: Ajwain, inter-cropping, net returns, LER, yield

Introduction
India is the world's largest producers, consumers and exporter of seed spices. Ajwain (*Trachyspermum ammi Sprague*) generally called as ''ajwain'' belongs to the Apiaceae family. It is mainly grown in Rajasthan, Gujarat, Madhya Pradesh, Tamilnadu and Uttar Pradesh. Ajwain is an important seed spice crop of Rajasthan which. Area, production and productivity of ajwain in Rajasthan are 0.06 lakh hectares, 0.04 lakh metric tones, and 680 kg ha^{-1}, respectively (Anonymous, 2015). Ahlawat and Gangaiah (2010) [1] reported higher system productivity in chickpea intercropped with linseed over sole chickpea. Mustard and chickpea intercropping have exhibited higher land equivalent ratio (1.41) over in sole crops (Thomas *et al.*, 2010) [8]. Shortages of vegetables in the country have focused the attention on intercropping systems which have capacity to improve the physical, biological and chemical properties of soil (Mehta *et al.*, 2010) [4]. Thus productivity of system can be enhanced with change in crop configuration for inclusion of other crops in the existing cropping system. Hence the study on effect of ajwain based inter-cropping system with vegetable crops was undertaken with an objective to find most efficient inter cropping system for realizing higher system productivity.

Material and Methods
The experiment was laid out at Research farm of ICAR-National Research Center on Seed Spices, Ajmer, Rajasthan, during *rabi* season of 2016-17. The soil of research farm is sandy loam, poor in fertility and water holding capacity, having pH 8.3 and organic carbon 0.23%, available N 100.38 kg ha^{-1}, P_2O_5 7.76 kg ha^{-1}, K_2O 392.26 kg ha^{-1}. The experiment comprising of 10 treatments *viz.*, sole ajwain, sole French radish, sole knolkhol, sole fenugreek, ajwain intercropping with French radish, knolkhol and fenugreek different row ratios (1:1 and 2:2) was laid in randomized block design with four replications.

As per technical programme one row of French radish, knolkhol and fenugreek was added between two rows of ajwain in 1:1 intercropping ratio and two rows of vegetable crops were added in a pair of two rows of ajwain (paired row having 25/35 cm). A uniform recommended dose of 60 Kg N and 40 kg P_2O_5 ha^{-1} and 30 kg K_2O for sole ajwain, 120 kg N, 60 kg P_2O_5 and 40 kg K_2O for sole knolkhol, 100 kg N, 50 kg P_2O_5 and 40 kg K_2O for french radish and 20 kg N, 40 kg P_2O_5 and 30 kg K_2 O for fenugreek was applied. In intercropping of ajwain and vegetables 100% NPK of sole ajwain and 50% NPK of respective vegetables were applied. 1/3 N and full dose of phosphorus and potash were applied at the time of sowing and remaining 2/3 N was applied with low pressure drip irrigation through urea at an interval of 8 days. The standard agronomic practices were applied for raising healthy ajwain crop as well as French radish, knolkhol and fenugreek. Immediately after sowing irrigation was provided with low pressure drip irrigation having normal operating pressure of 0.1 kg sq cm^{-1}. Each plot has 5 lateral lines of drip, the drippers were fitted on lateral lines at the distance of 30 cm. Each dripper had discharge rate of 1.25 litter $hour^{-1}$. First irrigation was given just after sowing and subsequent irrigations were provided at four days interval based on 80 CPE. Total 33 irrigations, each four days interval were given to crop starting from sowing to 15 days before harvesting. Yield of component crop was calculated based on proportionate area occupied by them. The yield of ajwain, French radish, knolkhol and fenugreek was converted into ajwain equivalent yield as per prevailing rates in market and treatment evaluation was done accordingly. Economic analysis of the different treatment was done for drawing conclusion.

Results and Discussion

Yield parameters and yield of ajwain

Significantly higher plant heights, number of branches $plant^{-1}$ at maturity of ajwain were recorded in sole ajwain over all intercropping systems (Table 1). In respect to intercropping systems, significantly higher growth parameters of ajwain were recorded with 1:1 ratio of ajwain and component crops *viz*. French radish, knolkhol and fenugreek. The higher plant height in sole ajwain and in 1:1 ratio intercropping was on account of less competition for sunlight, space, nutrient and water as compared to other ratio. Tiwari *et al*. (2002) [9] reported depressing effect on growth and performance of fennel when intercropped with vegetable crop. Similarly, Nandekar *et al*. (1995) [7] reported decrease in growth parameters of potato with intercropping.

The higher yield attributes and yield of ajwain with French radish, knolkhol and fenugreek intercrops were recorded in 1:1 ratio. Intercropping of ajwain with French radish resulted in significantly higher yield and yield attributes of ajwain over khnolkhol and fenugreek inter-cropping (Table 2).The higher yield attributes and yield of ajwain in 1:1 ratio with all intercrops might be due to less competition for space, sunlight, water and nutrients between ajwain and component crops which gave higher growth parameters resulting in higher translocation of photosynthates from source to sink resulting in higher yield and yield attributes of ajwain. Tiwari *et al*. (2002) [9] reported depressing effect on growth and performance of fennel when intercropped with vegetable crop. Similarly, Nandekar *et al.* (1995) [7] reported decrease in yield of potato with intercropping.

Yields attributes and yield of intercrops

Yield attributes and yield of intercrops was recorded higher in respective sole crops as compared to intercropping with ajwain. Further, perusal of data in Table 2 and 3 revealed that among different inter cropping ratios, the higher yield and yield attributes of intercrops was exhibited in 1:1 ratio. Intercropping of ajwain + French radish in all the ratios resulted higher economic yield of french radish as compared to knolkhol and fenugreek. The higher yield of all the intercrops crops in 1:1 ratio was on account of higher plant population due to accommodation of more number of rows in between interspaces as compared to 2:2 ratio. Mehta *et al.* (2012 and 2015) [5-6] also reported higher yield of intercrops in 1:1 row ratio with fennel

System productivity

Significantly higher ajwain equivalent yield (AEY) and land equivalent ratio (LER) of the system was recorded in intercropping as compared to sole cropping (Table 4). Ajwain + French radish in all intercropping ratios resulted higher AEY and LER as compared to its intercropping with knolkhol and fenugreek. Further analysis showed that 1:1 ratio with all intercrops proved superior resulting in higher AEY and LER over 2:2 ratio. Ajwain + French radish in 1:1 ratio exhibited 175.01 and 81% higher AEY and LER, respectively over sole ajwain. The higher AEY and LER in intercropping system was on account of additional yield of intercrops without much reduction in yield of base crop. The highest AEY and LER in 1:1 ratio with French radish, knolkhol and fenugreek was due to proportionately less reduction in ajwain yield as compared with 2:2 ratio resulting in better yield of intercrop. Bhati (1992) [2] and Mehta *et al.* (2015) [6] reported higher fennel equivalent yield in intercropping as compared to sole crops. Similarly, Ahlawat and Gangaiah (2010) [1] and also reported higher system productivity in chickpea intercropped with linseed over sole chickpea. Thomas *et al*. (2010) [8] reported the highest LER of 1.41 in mustard and chickpea intercropping over sole crops. Mehta *et al.* (2015) [6] also reported higher system productivity and LER on intercropping systems over sole intercropping.

Economic analysis

Intercropping of ajwain + French radish in 1:1 ratio exhibited significantly higher net return (Rs 270238 ha^{-1}) and B: C ratio (4.72) which was 175.01 and 81% higher, respectively over ajwain + French radish (2:2). Ajwain + French radish/knolkhol/fenugreek in 1:1 ratio proved superior which resulted in higher net return and B: C ratio over 2:2 ratio. Similar benefits of inter- cropping on economics in fenugreek + mustard was reported by Yadav *et al*, (2003) [10]. Khurana and Bhatia (1995) [2] in intercropping of onion and potato with fennel and Ahlawat and Gangaiah (2010) [1] in chickpea + linseed reported similar results.

It is concluded that intercropping of ajwain and French radish in 1:1 ratio is promising for higher productivity and profitability.

Table 1: Effect of intercropping system on growth and yield attributes of ajwain at harvest

Treatments	Plant height (cm)	Branches plant^{-1}	Umbels plant^{-1}	Umbellates umbel^{-1}	Seeds umbellate^{-1}	1000-seed weight (g)	Seed yield plant^{-1} (g)
Sole Ajwain	117.91	16.70	170.15	14.30	18.25	1.38	61.07
Sole French Radish	-	-	-	-	-	-	-
Sole Knolkhol	-	-	-	-	-	-	-
Sole Fenugreek	-	-	-	-	-	-	-
Ajwain + French Radish 1:1	110.09	15.80	169.65	14.20	17.95	1.25	54.18
Ajwain + French Radish 2:2	108.09	15.45	168.50	14.00	17.85	1.18	49.72
Ajwain + Knolkhol 1:1	109.96	15.75	169.10	14.20	17.95	1.23	52.92
Ajwain + Knolkhol 2:2	108.13	15.40	168.45	14.00	17.75	1.16	48.65
Ajwain + Fenugreek 1:1	109.09	15.65	169.30	14.10	17.95	1.21	51.86
Ajwain + Fenugreek 2:2	108.05	15.15	168.20	13.95	17.85	1.13	47.34
SEm±	2.88	0.64	3.61	0.44	0.47	0.04	2.13
CD (P=0.05)	NS	NS	NS	NS	NS	NS	6.32

Table 2: Effect of intercropping system on growth and yield attributes of component crops

Treatments	Plant population	Plant height (cm)	No. of leaves plant^{-1}	Days to maturity	Days to harvest
Sole Ajwain	-	-	-	-	-
Sole French Radish	2.26	44.96	14.80	51.05	53.80
Sole Knolkhol	2.24	34.26	24.03	64.10	-
Sole Fenugreek	2.24	30.69	25.96	-	54.95
Ajwain + French Radish 1:1	2.15	43.19	14.05	48.75	51.70
Ajwain + French Radish 2:2	1.70	42.25	13.95	48.20	51.00
Ajwain + Knolkhol 1:1	2.10	33.01	23.10	63.35	-
Ajwain + Knolkhol 2:2	1.80	32.08	22.05	62.85	-
Ajwain + Fenugreek 1:1	2.15	29.39	25.75	-	54.30
Ajwain + Fenugreek 2:2	1.80	29.22	25.25	-	54.20
SEm±	-	-	-	-	-
CD (P=0.05)	-	-	-	-	-

Table 3: Effect of intercropping systems on yield of ajwain and component crops and system productivity (ajwain equivalent yield)

Treatments	Seed yield of Ajwain (Q ha^{-1})	Marketable yield of intercrops (Q ha^{-1})	Ajwain equivalent yield
Sole Ajwain	13.77	-	13.77
Sole French Radish	-	274.30	21.94
Sole Knolkhol	-	138.84	13.84
Sole Fenugreek	-	273.39	21.84
Ajwain + French Radish 1:1	12.21	256.61	32.74
Ajwain + French Radish 2:2	11.18	254.70	31.56
Ajwain + Knolkhol 1:1	11.90	121.79	24.09
Ajwain + Knolkhol 2:2	10.94	113.76	22.32
Ajwain + Fenugreek 1:1	11.69	246.53	31.42
Ajwain + Fenugreek 2:2	10.63	237.75	29.65
SEm±	4.80	-	0.89
CD (P=0.05)	14.10	-	2.58

Table 4: Effect of intercropping systems on economics and land equivalent ratio (LER)

Treatments	Cost of cultivation (Rs ha^{-1})	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	B:C ratio	LER
Sole Ajwain	53000	137700	84700	1.59	1.00
Sole French Radish	61550	138440	157890	2.56	1.00
Sole Knolkhol	64300	138440	74140	1.15	1.00
Sole Fenugreek	66050	218712	152662	2.31	1.00
Ajwain + French Radish 1:1	57150	327388	270238	4.72	1.81
Ajwain + French Radish 2:2	57150	315660	258510	4.52	1.73
Ajwain + Knolkhol 1:1	58950	240890	181940	3.08	1.73
Ajwain + Knolkhol 2:2	58950	223160	164210	2.75	1.61
Ajwain + Fenugreek 1:1	60038	314224	254186	4.23	1.74
Ajwain + Fenugreek 2:2	60038	296500	236462	3.93	1.63
SEm±	-	-	-	0.05	0.05
CD (P=0.05)	-	-	-	0.15	0.15

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